АКАДЕМИЈА НАУКА И УМЈЕТНОСТИ РЕПУБЛИКЕ СРПСКЕ

НАУЧНИ СКУПОВИ
Књига XXVIII

ОДЈЕЉЕЊЕ ПРИРОДНО-МАТЕМАТИЧКИХ И ТЕХНИЧКИХ НАУКА
Књига 22

САВРЕМЕНИ МАТЕРИЈАЛИ

Бања Лука 2014

Научни скуп

САВРЕМЕНИ МАТЕРИЈАЛИ

Зборник радова

ACADEMY OF SCIENCES AND ARTS OF
THE REPUBLIC OF SRPSKA

SCIENTIFIC CONFERENCES
Book XXVIII

DEPARTMENT OF NATURAL-MATHEMATICAL AND
TECHNICAL SCIENCES
Book 22

CONTEMPORARY MATERIALS

Banja Luka 2014

АКАДЕМИЈА НАУКА И УМЈЕТНОСТИ
РЕПУБЛИКЕ СРПСКЕ

НАУЧНИ СКУПОВИ
Књига XXVIII

ОДЈЕЉЕЊЕ ПРИРОДНО-МАТЕМАТИЧКИХ И
ТЕХНИЧКИХ НАУКА
Књига 22

САВРЕМЕНИ МАТЕРИЈАЛИ

ГЛАВНИ УРЕДНИК
Академик Рајко Кузмановић

ОДГОВОРНИ УРЕДНИК
Академик Драгољуб Мирјанић

Бања Лука 2014

ОРГАНИЗАЦИОНИ ОДБОР
НАУЧНОГ СКУПА

Академик Рајко Кузмановић, предсједник
Академик Драгољуб Мирјанић, потпредсједник
Академик Васкрсија Јањић
Академик Бранко Шкундрић
Проф. др Симо Јокановић
Проф. др Зоран Рајилић
Доц. др Момчило Биуковић
Мр Винко Богдан
Доц. др Синиша Вученовић

НАУЧНИ ОДБОР
НАУЧНОГ СКУПА

Академик Драгољуб Мирјанић
Академик Бранко Шкундрић
Академик Јован Шетрајчић
Академик Стане Пејовник (Словенија)
Академик Пантелија Дакић
Проф. др Нeђо Ђурић, дописни члан АНУРС-а
Академик Томислав Павловић (Србија)
Академик Ростислав Андриевски (Русија)
Академик Филип Говоров (Украјина)
Академик Џералд Полак (САД)
Проф. др Румиана Тсенкова (Јапан)
Проф. др Мај Ван Хо (Велика Британија)
Проф. др Ифа Говен (Ирска)
Проф. др Јукио Косуги (Јапан)
Др Мајрон Д. Еванс (Канада)
Проф. др Мартин Чаплин (Велика Британија)
Проф. др Ђуро Коруга (Србија)
Проф. др Драгица Лазић
Проф. др Перо Дугић
Проф. др Слободан Чупић

С А Д Р Ж А Ј

INFLUENCE OF NANOMATERIAL-BASED CONTACT LENSES ON SOLUTIONS WITH DIFFERENT GLUCOSE CONCENTRATIONS

J. Šakota Rosić[1], M. Tomić[1], N. Milojević[2], G. Nikolić[1], Đ. Koruga[1]

[1] NanoLab, Biomedical Engineering, Faculty of Mechanical Engineering, University of Belgrade, Serbia

[2] Intellectual Property Office, Belgrade, Serbia

Abstract: Goal of this research is focusing on early detection of high glucose level in blood via eye, using contact lenses, because we have come to conclusion that skin is not the most suitable place for measuring glucose level, considering invasive and expensive techniques. These specific contact lenses, made of biocompatible nanostructured materials, present biosensors for continuous, noninvasive glucose monitoring and other bioanalits which can be found in tears.

In this paper we present the comparative studies of the influence of nanomaterial-based contact lenses on five solutions with different glucose concentrations. The nanophotonic contact lens and contact lens made from base material were dipped in solutions over a specific period of time, in order to determine their influence on the glucose solutions. The base material of contact lens was made from PMMA and the nanophotonic contact lenses were made of fullerene doped PMMA. Fullerenes were used because of their good transitive characteristics in ultraviolet, visible and near infrared light spectrums. Measurements were done at room temperature. Results of all solutions are presented and compared.

Key word: Contact lenses, glucose, fullerene, OMIS.

INTRODUCTION

Diabetes (diabetes mellitus) is a chronic, incurable systemic metabolic disorder characterized by hyperglycemia or hypoglycemia. Today is one of the most common endocrine diseases, with the prevalence increasing (especially in developed countries). This is a consequence of modern lifestyles [1].

Statistical data from the latest research shows that 25,8 million (8,3%) children and adults in the United States have diabetes. It is assumed that 79 million people in the United States suffers from prediabetes. In 2007, diabetes was listed as the underlying cause on 71.382 death certificates and was listed as a contributing factor on an additional 160.022 death certificates. This means that diabetes contributed to a total of 231.404 deaths [9].

Next to heart diseases, stroke, high blood pressure, kidney disease, nervous system disease (neuropathy), amputation, diabetes is the leading cause of new cases of blindness among adults aged 20–74 years. In 2005–2008, 4,2 million (28,5%) people with diabetes aged 40 years or older had diabetic retinopathy, and of these, almost 0,7 million (4,4% of those with diabetes) had advanced diabetic retinopathy that could lead to severe vision loss [9].

Total costs of diagnosed diabetes in the United States in 2012 amounted \$245 billion. \$176 billion for direct medical costs, and \$69 billion in reduced productivity. For blood glucose test strips each year a nearly \$ 7 billion is spent [1]. For the purpose of cost reduction and improvement of monitoring changes in glucose levels in people with diabetes new types of contact lenses doped with fullerenes are produced.

In this paper we present the investigation of influence of three sorts of contact lenses on solutions with different glucose concentrations. Analysis of influence on different solutions were made for standard contact lenses and contact lenses with fullerene C_{60}, fullerol $C_{60}(OH)_{24}$ and metformin hydroxylate fullerene $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$. Opto-magnetic imaging spectroscopy method was used for characterizing the samples.

MATERIALS

For purposes of this research, we used four types of materials: SP40^{TM}, fullerene SP40+C_{60}, fullerol SP40+$C_{60}(OH)_{24}$, and metformin hydroxylate fullerene SP40+$C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$.

Thin plates of SP40^{TM} which were purchased from manufacturer Soleko, Italy [11] were used for making gas-permeable (RGP) contact lenses. The visible transmittance of these contact lenses is less than 90%, ultraviolet transmittance is less than 60%, and its refractive index is 1,472 [10].

In our investigation we used three different sorts of nanomaterials: fullerene C_{60}, fullerol $C_{60}(OH)_{24}$ and metformin hydroxylate fullerene SP40+$C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$. One gram of each nanomaterial was added during the polymerization process to the standard polymethylmethacrylate material, SolekoSP40^{TM} [2]. The percentage of nanoparticles in solution was 0,33%, but they are not completely dissolved in MMA. Polymerization was homogeneous in all samples therefore new so-called photonic nanomaterials for RGP contact lenses were obtained. The third polymerization was carried out without nanomaterial, which is a regular Soleko SP40 RGP material, from which we made contact lenses, serving as the reference sample [3].

Spectroscopic properties of fullerenes are closely related to their symmetry [4]. Structural information can be obtained from the number of connections, for example in the IR spectrum. C_{60} has a very low solubility and high crystallinity. Also, the C_{60} fullerene and its derivatives show different excellent electronic, conductive, magnetic and photochemical properties, but their processing is weak. Therefore, they have many potential applications if they are in polymers, such as the C_{60} incorporated into PMMA. Polymers are brown and the colour becomes darker with increasing C_{60} content in the polymer, whose addition also improves the thermal stability of polymers. One of the main disadvantages in fullerene applications is its low solubility in water. In order to make them soluble, they must be functionalized with polar groups such as –OH and –COOH [6]. Polymer systems containing C_{60} molecules show different solubility and formed aggregates at the nano level, which have interesting morphologies.

The properties of C_{60} can also be modified by its incorporation into polymers making it a material that can be easily handled and produced (Figure 1). Therefore, combination of both systems has led to a wide variety of new materials showing appealing features based on the possibility of tuning their properties by modifying the chemical nature of the components or the chemical linkage between them [5].

Also, five solutions with different glucose concentrations have been used for dipping nanophotonic contact lens and contact lens made from base material over a specific period of time.

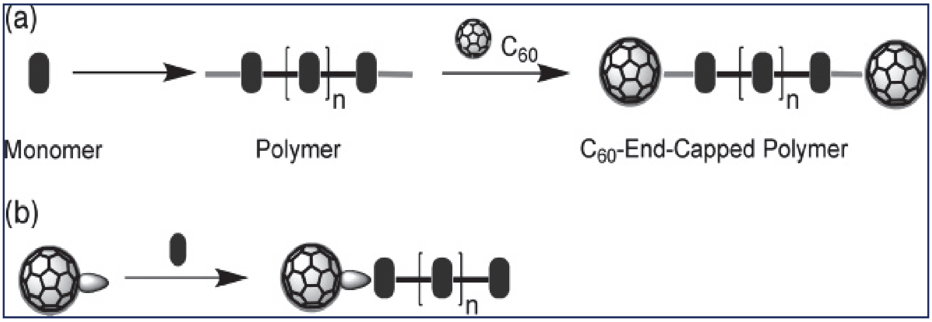


Figure 1. Synthetic strategies for the synthesis of C_{60}-end-capped polymers [7].

METHODS

For the characterization of solutions with different glucose concentrations we used one type of spectroscopy method: opto-magnetic imaging spectroscopy (OMIS). All measurements were performed in air at room temperature.

OPTO-MAGNETIC IMAGING SPECTROSCOPY METHOD (OMIS)

Each type of matter has special, different, angle value of light polarization. When the incident white light is diffuse, the reflected white light is composed of electrical and magnetic components, whereas diffuse incident light that is inclined under certain angle will produce reflected light which contains only electrical component of light (figure 2). This angle is called Brewster's angle and it represents the magnitude of the angle of incidence under which the sample polarizes the incident light. Taking the difference between white light (electromagnetic) and reflected polarized light (electrical) yields magnetic properties of matter based on light-matter interaction. Because such measurement can identify the conformational state and change in tissue on molecular level we named this method the opto-magnetic imaging spectroscopy [8].

The equipment for recording was a Canon digital camera, model IXUS 105, 12.1 MP. The light solution was accomplished by diffuse white diode and a lighting composition at Brewster's angle (three LED set at angle of 60˚ in regard to vertical axes). The recording region is circular with diameter of about 25 mm. In addition to customized camera, a software solution is used for analyzing the obtained images, yielding a characteristic diagram – diagnostic result – showing the intensities of light in correspondence with wavelength difference. Since this light is polarized by the sample that means that the character of polarization describes the character of the material. In this way, by characterizing the reflected light we can actually characterize the properties of the sample. This method is very sensitive since it detects magnetic properties on the basis of the response to visible light excitation which is relatively low in energy [8].

In this part of the research we used four types of contact lenses: standard SP40, SP40 with C_{60} incorporated, SP40 with $C_{60}(OH)_{24}$ incorporated, and SP40 with $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$. The solutions with different glucose concentrations, were poured into cups of 20 ml, and the contact lenses were put into those solutions. The solutions with contact lenses were left for 168 hours. After 168 hours, the contact lenses were taken out of the solutions, and the solutions were poured in other cups for taking pictures. Every sample was shot 10 times, with white and reflected polarized light. The pictures of solutions, without influence of contact lenses, were taken as well, for comparison.

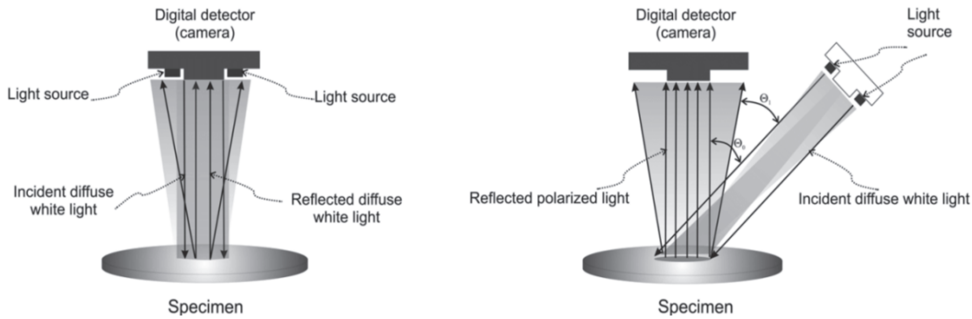
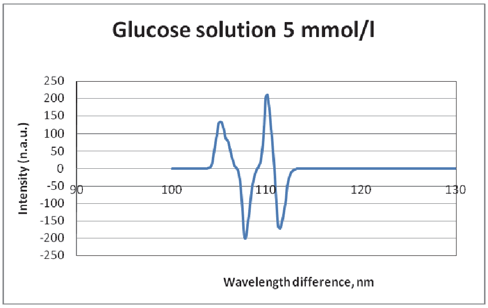
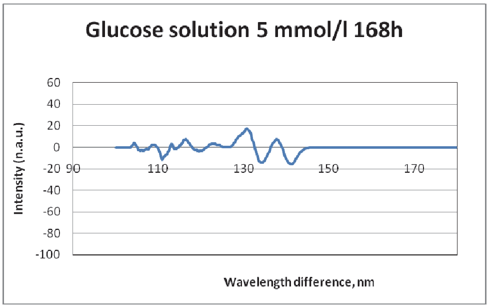


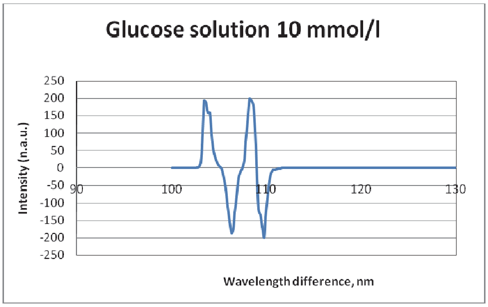
Figure 2. Operational principle of opto-magnetic imaging spectroscopy method [8].

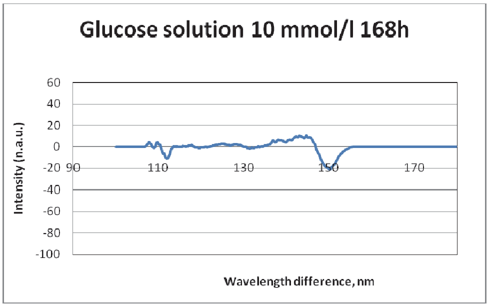
RESULTS

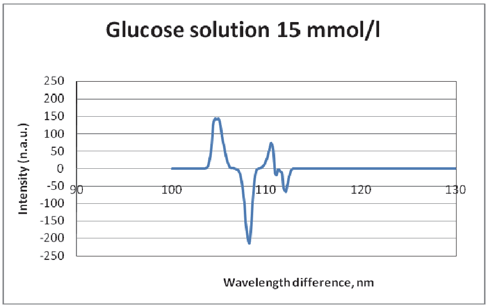
By analyzing average spectrums diagrams we can see the differences and similarities, on the diagrams from the same class (Figure 3). It is obvious that all solutions with different glucose concentrations have four peaks, two positive and two negative.

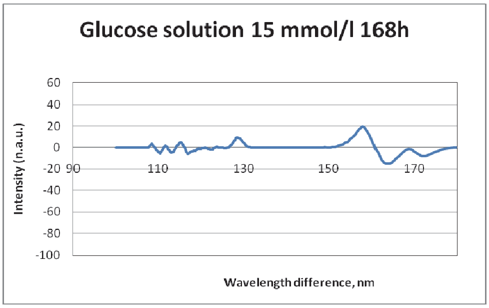


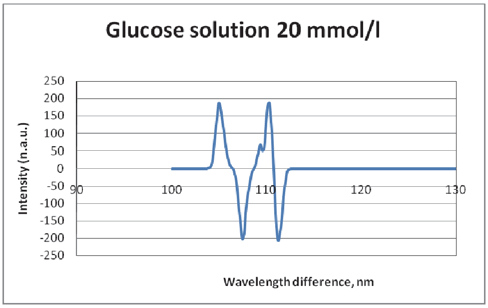


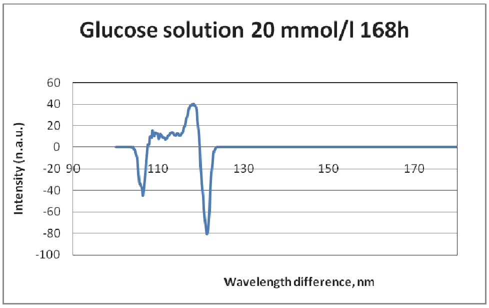












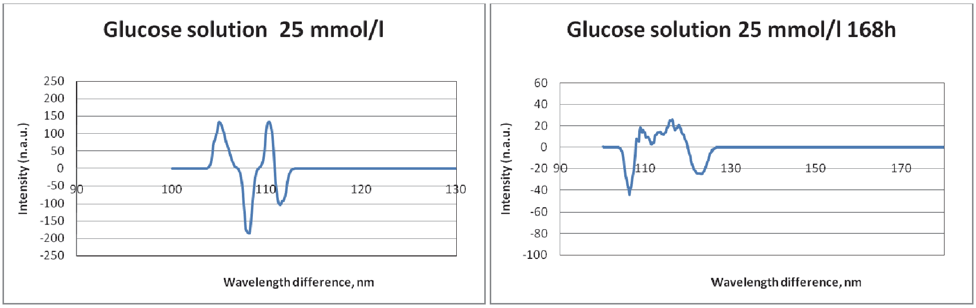


Figure 3. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for solutions with different glucose concentrations

For glucose solution with concentration of 5 mmol/l average wavelengths and amplitudes for the first and the second positive peak are 104,97/129,25 and 109,96/200,44, respectively, and for the first and the second negative peak they are 107,66/-198,31 and 111,31/-165,90. On the other hand, those peaks after 168 hours are at 129,67/12,93 and 136,80/4,22, and negative ones at 133,28/-10,85 and 140,37/-13,35.

For glucose solution with concentration of 10 mmol/l average wavelengths and amplitudes for the first and the second positive peak are 103,44/192,98 and 108,24/197,81, respectively, and for the first and the second negative peak they are 106,32/-185,66 and 109,77/-199,36. However, those peaks after 168 hours are at 107,28/1,93 and 142,30/9,74, and negative ones at 110,93/-4,64 and 149,10/-18,02.

For glucose solution with concentration of 15 mmol/l average wavelengths and amplitudes for the first and the second positive peak are 104,60/142,56 and 110,54/72,47, respectively, and for the first and the second negative peak they are 108,05/-196,52 and 111,86/-53,53. Furthermore, those peaks after 168 hours are at 127,61/6,06 and 156,75/15,41, and negative ones at 162,80/-13,78 and 171,43/-7,37.

For glucose solution with concentration of 20 mmol/l average wavelengths and amplitudes for the first and the second positive peak are 104,98/185,50 and 110,16/174,72, respectively, and for the first and the second negative peak they are 107,48/-202,64 and 111,31/-206,46. However, those peaks after 168 hours are at 108,62/15,20 and 117,33/37,31, and negative ones at 106,13/-39,30 and 121,48/-80,73.

For glucose solution with concentration of 25 mmol/l average wavelengths and amplitudes for the first and the second positive peak are 104,98/131,70 and 110,16/128,67, respectively, and for the first and the second negative peak they are 107,86/-172,02 and 111,31/-97,36. On the other hand, those peaks after 168 hours are at 108,62/14,58 and 115,53/22,73, and negative ones at 105,94/-37,24 and 121,22/-19,55.

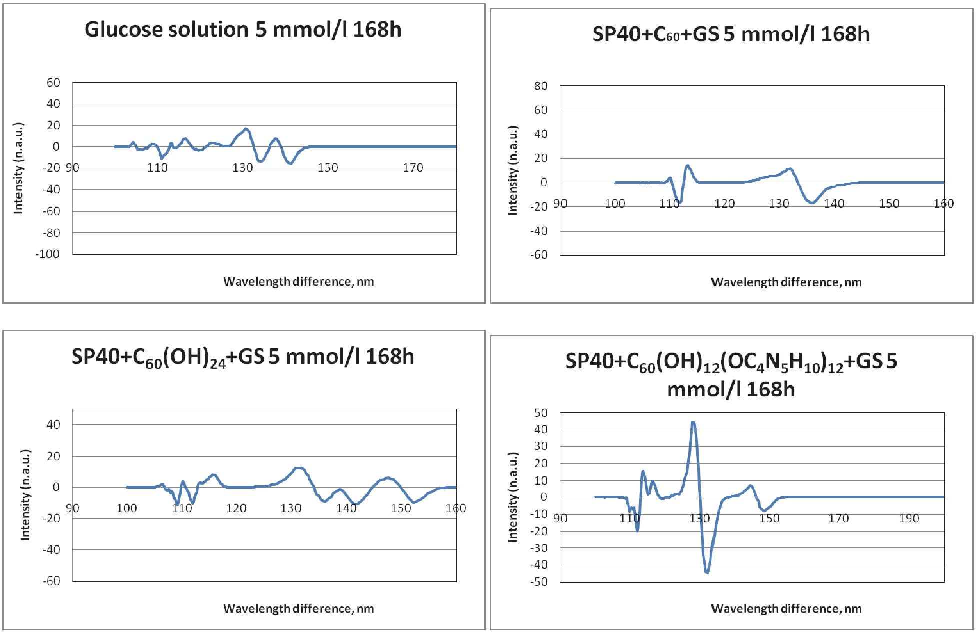


Figure 4. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for glucose solution with concentration of 5 mmol/l with contact lens with C_{60} (SP40+C_{60}+GS), glucose solution with contact lens with $C_{60}(OH)_{24}$ (SP40+$C_{60}(OH)_{24}$+GS) and glucose solution with contact lens with $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ (SP40+ $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$+GS)

The positive peaks for the glucose solution with concentration of 5 mmol/l under influence of C_{60} are at 113,04/13,20 and 130,77/9,33, and the first and the second negative peak are at 110,93/-10,40 and 134,86/-14,29. When glucose solution was under influence of $C_{60}(OH)_{24}$ the positive peaks are at 115,73/7,98 and 131,07/12,34, and the negative peaks are at 111,87/-10,10 and 151,83/-8,32, respectively. The differences in wavelengths are approximately 2 nm and 1 nm for positive peaks, and approximately 1 nm and 17 nm, and for intensities approximately 0,3 units and 6 units for the negative peaks and 6 units and 3 units for the positive ones. In the case of influence of the contact lens with incorporated $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ on the glucose solution there are four peaks, two positive and two negative. The first positive peak is at 113,42/14,39 and the second is at 127,89/44,50, and the negative ones are at 111,69/-15,05 and 131,71/-44,13.

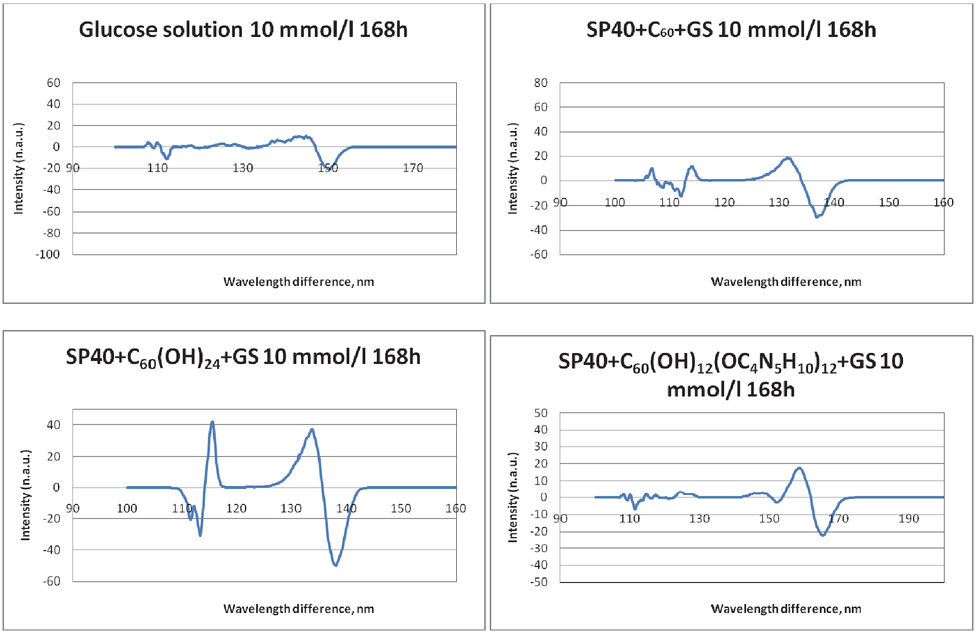


Figure 5. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for glucose solution with concentration of 10 mmol/l with contact lens with C_{60} (SP40+C_{60}+GS), glucose solution with contact lens with $C_{60}(OH)_{24}$ (SP40+$C_{60}(OH)_{24}$+GS) and glucose solution with contact lens with $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ (SP40+ $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$+GS)

The positive peaks for the glucose solution with concentration of 10 mmol/l under influence of C_{60} are at 113,61/9,86 and 130,28/14,17, and the first and the second negative peak are at 111,70/-9,61 and 136,43/-24,92. When glucose solution was under influence of $C_{60}(OH)_{24}$ the positive peaks are at 115,72/38,35 and 133,68/37,55, and the negative peaks are at 113,42/-27,69 and 137,62/-48,30, respectively. The differences in wavelengths are approximately 2 nm and 3 nm for positive peaks, and approximately 2 nm and 1 nm, and for intensities approximately 18 units and 24 units for the negative peaks and 29 units and 23 units for the positive ones. In the case of influence of the contact lens with incorporated $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ on the glucose solution there are four peaks, two positive and two negative. The first positive peak is at 124,44/3,25 and the second is at 158,40/17,47, and the negative ones are at 110,92/-4,04 and 164,97/-22,02.

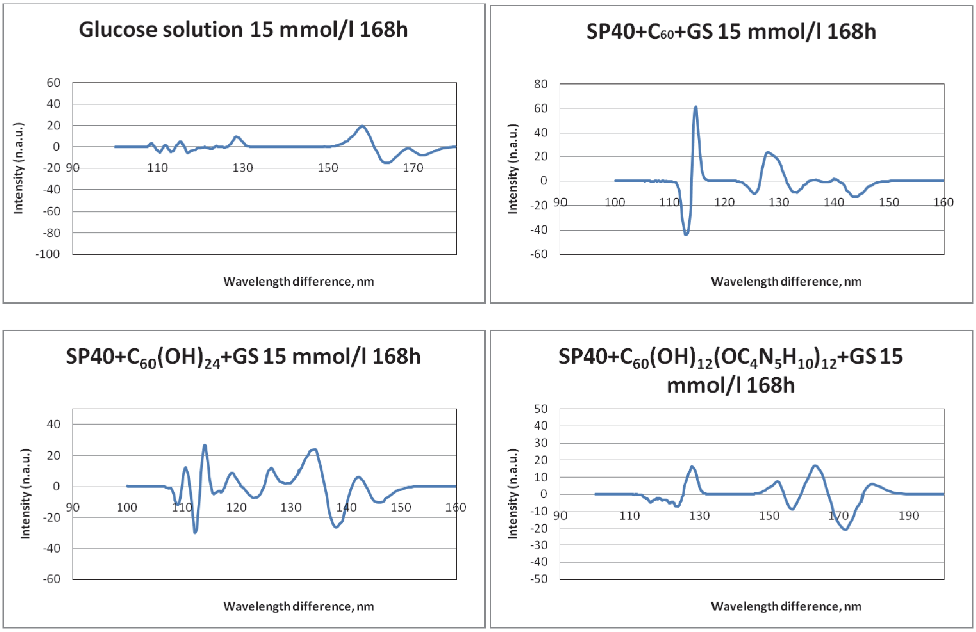


Figure 6. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for glucose solution with concentration of 15 mmol/l with contact lens with C_{60} (SP40+C_{60}+GS), glucose solution with contact lens with $C_{60}(OH)_{24}$ (SP40+$C_{60}(OH)_{24}$+GS) and glucose solution with contact lens with $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ (SP40+ $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$+GS)

The positive peaks for the glucose solution with concentration of 15 mmol/l under influence of C_{60} are at 114,57/59,40 and 127,60/22,70, and the first and the second negative peak are at 112,46/-35,41 and 143,09/-11,55. When glucose solution was under influence of $C_{60}(OH)_{24}$ the positive peaks are at 113,99/26,45 and 133,68/23,68, and the negative peaks are at 112,27/-29,70 and 137,62/-24,60, respectively. The differences in wavelengths are approximately 1 nm and 6 nm for positive peaks, and approximately 0 nm and 6 nm, and for intensities approximately 33 units and 1 units for the negative peaks and 6 units and 13 units for the positive ones. In the case of influence of the contact lens with incorporated $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ on the glucose solution there are four peaks, two positive and two negative. The first positive peak is at 127,89/16,30 and the second is at 162,80/16,65, and the negative ones are at 156,24/-8,63 and 171,43/-20,28.

CONCLUSION

According to the diagrams of five solutions with different glucose concentrations there is a dramatic difference in the values of the positive and negative peaks on Wavelength difference (nm)-Intensity (n. a. u.). Therefore we can conclude that glucose is dissolved within 168 hours, which is of great importance for the further course of this experiment.

The acquired Wavelength difference (nm)-Intensity (n. a. u.) diagrams show that all three sorts of contact lenses have almost the same influence on all three glucose solutions. For all three glucose solutions before adding the contact lenses there are no significant peaks, neither positive nor negative. The diagrams are almost the same before putting the contact lenses for all three glucose solutions. Also, it is obvious that all three types of contact lenses have certain reactions with solutions with different glucose concentrations.

In the case of glucose solution with concentration of 5 mmol/l under influence of contact lenses with incorporated C_{60} and $C_{60}(OH)_{24}$ the diagrams are slightly different. It is obvious that these sorts of contact lenses have slight influences on solution with concentration of 5 mmol/l, while we can conclude that contact lens with $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ has the biggest influence on this glucose solution. Also it is marked that the peaks appear at wavelengths in range of 112 nm to 171 nm, while intensities have bigger variations.

In the case of glucose solution with concentration of 10 mmol/l under influence of contact lenses with incorporated C_{60} and $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ the diagrams are slightly different. It is obvious that those sorts of contact lenses have slight influences on solution with concentration of 10 mmol/l, while we can conclude that contact lens with incorporated $C_{60}(OH)_{24}$ has the biggest influence on this glucose solution. Also it is marked that the peaks appear at wavelengths in range of 110 nm to 164 nm, while intensities have bigger variations.

In the case of glucose solution with concentration of 15 mmol/l under influence of contact lenses with incorporated $C_{60}(OH)_{24}$ and $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$ the diagrams are slightly different. It is obvious that those sorts of contact lenses have slight influences on solution with concentration of 15 mmol/l, while we can conclude that contact lens with incorporated C_{60} has the biggest influence on this glucose solution. Also it is marked that the peaks appear at wavelengths in range of 112 nm to 171 nm, while intensities have bigger variations.

The aim of this work was to investigate the influence of contact lenses made of different materials, the standard SP40 material and SP40 material with incorporated nanomaterials (C_{60}, C_{60} $(OH)_{24}$) and $C_{60}(OH)_{12}(OC_4N_5H_{10})_{12}$) on liquids that have similar concentration of glucose as tear film.

Finally, we can conclude that it is possible to detect the differences in influences of contact lenses on glucose solutions with opto-magnetic imaging spectroscopy method, and according to acquired diagrams there are differences and similarities of influences of different contact lenses.

Acknowlegment: This research are supported by Ministry of Education, Science and Tecnological Development, Project III41006.

REFERENCE:

[1] P. Grant: *The perfect diabetes review*, Primary care diabetes 2010, 4: 69–72.

[2] M. Tomić, D. Stamenković, N. Jagodić, J. Šakota, L. Matija; *Influence of contact lenses material on aqueous solutions*, Contemporary Materials, III–1 (2012), Page 93 of 99.

[3] D. Stamenković, N. Jagodić, M. Conte, N. Ilanković, T. Jovanović, Đ. Koruga: *Optical Properties of Nanofotonic Contact Lenses*, Twelfth Annual Conference YUCOMAT 2010, Herceg Novi, 2010.

[4] Đ. Koruga, A. Tomić: *Optomagnetic fingerprint*, Nanotechnology handout, lesson 8, Faculty of mechanical engineering University of Belgrade, 2010.

[5] F. Giacalone and N. Martín: *Fullerene polymers: synthesis and properties*, Chem. Rev. 106, 2006, 5136–5190

[6] Đ. Koruga: *Composition of Matter Containing Harmonized Hydroxyl Modified Fullerene Substance*, US Patent 8,058,483 B2, November 15, 2011.

[7] F. Giacalone and N. Martín: *Fullerene Polymers: Synthesis, Properties and Application*, Wiley-VCH VerlagGmbH & Co. Weinheim, 2009.

[8] Đ. Koruga and A. Tomić, *System and Method for Analysis of Light-matter Interaction Based on Spectral Convolution*, US Patent Pub. No.: 2009/0245603, 2009.

[9] http://www.diabetes.org

[10] http://eurotechoptical.com

[11] C. Snyder: *A Primer on Contact Lens Materials; Different ingredients and manufacturing processes determine the properties and characteristics of modern contact lens materials*, OD, MS, FAAO, 2010.

УТИЦАЈ КОНТАКТНИХ СОЧИВА ИЗРАЂЕНИХ ОД НАНОМАТЕРИЈАЛА НА РАСТВОРЕ ГЛУКОЗЕ РАЗЛИЧИТИХ КОНЦЕНТРАЦИЈА

Апстракт: Циљ овог истраживања је фокусирање на рану детекцију повишеног нивоа глукозе у крви преко ока, применом контактних сочива, зато што је установљено да кожа и није најадекватније место за мерење нивоа глукозе, с обзиром на инвазивне и скупе методе. Ова специфична контактна сочива, направљена од наноструктурираних материјала, представљају биосензоре за континуално, неинвазивно праћење нивоа глукозе и других биоаналита који се могу наћи у сузама.

У овом раду представљамо упоредну студију утицаја нанофотоничних сочива на пет раствора глукозе различитих концентрација. Нанофотонична контактна сочива и контактна сочива израђена од основних материјала потопљена су у растворе током одређеног временског периода, са циљем да се утврди њихов утицај на растворе глукозе. Основни материјал за контактна сочива направљен је од PMMA, а нанофотонична контактна сочива израђена су од PMMA допираног фулереном. Фулерени су коришћени због својих добрих пропусних карактеристика у домену ултраљубичасте, видљиве и блиске инфрацрвене светлости. Мерења су рађена на собној температури. Резултати свих раствора презентовани су и упоређени.

Кључне речи: контактна сочива, глукоза, фулерени, OMIS.